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(54) Liquid discharge apparatus having magnetic valve

(57) A liquid discharge apparatus, such as a nebulizer, discharges liquid droplets by supplying the liquid to a vibrating element having a plurality of openings. A valve between a reservoir for the liquid and the element has a tube extending toward the vibrating element. The tube has a valve seat. The tube extends through a magnetic coil in the body of the nebulizer. A ferromagnetic stopper is positioned in the tube and biased toward the valve seat. Energization of the magnetic coil lifts the stopper off the valve seat to allow liquid to flow to the vibrating element. In the alternative, the valve may be placed in the reservoir for operation by a ferromagnetic actuator. The coil may include an electrode for measuring, in conjunction with the vibrating element, an impedance indicative of the amount of liquid provided to the element. The impedance so measured may be used to control the amount of liquid supplied from the reservoir.

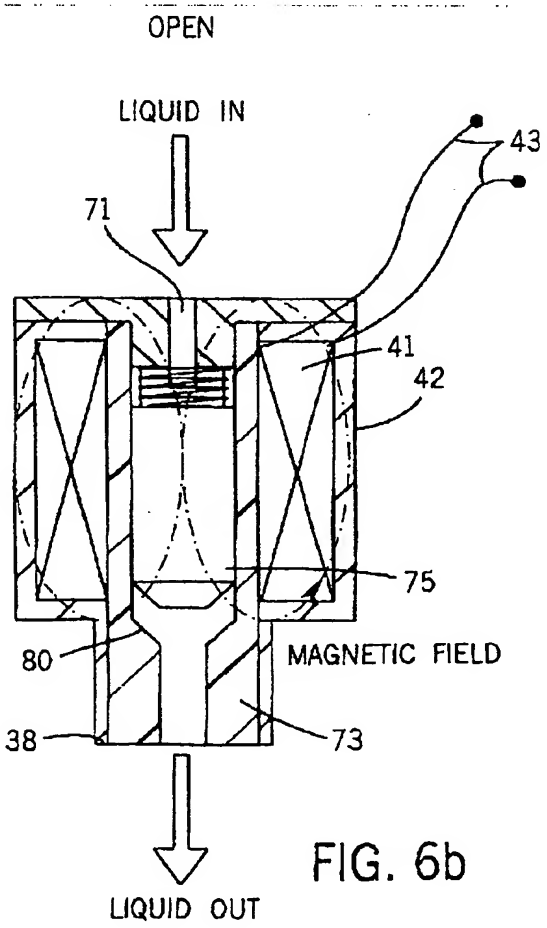

FIG. 6b

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parts of the nebulizer may, furthermore, be in contact with different anaesthetic agents in the breathing gases, which are specific to each subject. Those parts should also be cleaned or changed when changing to a different patient. Still other parts of the nebulizer are in contact with the pharmaceutical drug administered to a given subject. These parts should be cleaned when changing to a different drug or a different subject.

[0010] The foregoing problems have increased the cost and complexity, and reduced the ease of use of liquid discharge apparatus.

BRIEF SUMMARY OF THE INVENTION

[0011] An object of the present invention is to provide an improved apparatus having an accurate liquid supply system to supply liquid to a displaceable element so that it can be efficiently discharged from the apparatus. Another object of the invention is to provide an apparatus having a liquid supply system in which those parts that are exposed to the liquid during operation are changeable or/and disposable to reduce the cleaning work when changing liquids or, if the apparatus is a drug dispensing nebulizer, when changing subjects.

[0012] The above and other objects are attained by a liquid discharge apparatus comprising liquid discharge means, such as a mesh plate connected to a piezoelectric vibrating means. The apparatus also comprises a liquid supply system including a valve having, in one embodiment, a fixed part and a changeable or disposable part to control the liquid flow to the liquid discharge means via a liquid conveying means. The liquid supply system has a liquid reservoir attached to the changeable part of the valve from which the liquid is fed to the valve. The fixed part of the valve includes an electromagnet. A ferromagnetic member is positioned in the magnetic field to control liquid flow through the liquid conveying means. A liquid detection system detects the liquid arriving at the liquid discharge means from the liquid reservoir and controls the valve which regulates the liquid flow using the fixed part of the valve.

[0013] In another embodiment, the valve is placed in the liquid reservoir and the liquid supply system includes an actuator for the valve.

[0014] Various other features, objects, and advantages of the invention will be made apparent from the following detailed description and the accompanying drawing.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0015] In the drawings:

Fig. 1 is a general cross sectional view of the liquid discharge apparatus of the present invention, the operating environment for the apparatus being shown in generalized schematic form;

Fig. 2 is an exploded, cross sectional view showing the apparatus of the present invention;

Figs. 3a and 3b are cross sectional views showing the filling of the liquid reservoir of the apparatus of Fig. 1;

Figs. 4a and 4b are schematic views showing the operation of the vibrating and atomizing means of the apparatus of Fig. 1;

Fig. 5a-1 and 5a-2 are cross-sectional schematic views of components of a valve incorporated in the liquid discharge apparatus;

Figs. 5b-1 and 5b-2 are generally orthogonal views of one embodiment of the part of the valve shown in Fig. 5a-1 that controls liquid flow from through the valve;

Figs. 5b-3 and 5b-4 are generally orthogonal views of another embodiment of the part of the valve shown in Fig. 5a-a that controls liquid flow through the valve;

Figs. 6a and 6b are cross-sectional, schematic views showing operation of the valve of Fig. 5;

Figs. 7 is a cross sectional, exploded schematic view of another embodiment of a valve suitable for use in the liquid discharge apparatus of the present invention;

Figs. 8a and 8b are cross sectional, schematic views showing the operation of the valve of Fig. 7;

Fig. 9 shows a further embodiment of a valve suitable for use in the liquid discharge apparatus of the present invention; and

Fig. 10a and 10b are cross sectional schematic views showing the operation of the valve of Fig. 9.

DETAILED DESCRIPTION OF THE INVENTION

[0016] Liquid discharge apparatus 1 of the present invention is shown as a nebulizer in Fig. 1 and is typically used in conjunction with breathing circuit 2, ventilator 3 and control unit 4. The nebulizer apparatus 1 atomizes liquid solutions or suspensions for delivery to a subject, as for example as a drug treatment for a patient. Breathing circuit 2 includes inhalation limb 5, which is coupled to ventilator 3 at inhalation limb connector 6. Exhalation limb 7 is connected to ventilator 3 at exhalation limb connector 8. Inhalation limb 5 and exhalation limb 7 are connected to two arms of Y-connector 9. A third arm of Y-connector 9 is connected to one end of patient limb 10. The other end of patient limb 10 is directed to a mouthpiece, facemask, or endotracheal tube for the subject,

[0017] Ventilator 3 provides all or a portion of the breathing gases for the subject by providing inhalation gases in inhalation limb 5. The inhalation gases pass through Y-connector 9 and into patient limb 10 for supply to the subject On exhalation, the breathing gases pass through patient limb 10, Y-connector 9, and exhalation limb 7 back to ventilator 3.

[0018] As shown in Fig. 1, the nebulizer apparatus 1 is preferably positioned in patient breathing circuit 2 as

tive material, such as plastic, and is placed in the cavity 28 defined by the housing 22. Lower part of plug member 30 has two power terminals 35 and 36 made of conductive material. Plug member 30 is placed on top of plate 50 so that the plate is between the electrodes and projecting parts 24 and 25. The terminal 35, which terminal may be in the form of a ring- shaped spring, contacts piezoelectric element 56 and is connected to cable 20 through the plug member 30. A second electrical power terminal 36, also connected to cable 20 through plug member 30, contacts conductive plate 50. Terminal 36 may be electrically grounded for purposes of applying a voltage to piezoelectric element 56 in conjunction with terminal 35.

[0027] Tubular sensing electrode 38, which is close to the upper surface of mesh plate 52, is used for impedance measurement of the presence of liquid in nebulizer apparatus 1 in conjunction with plate 50 which is opposite the sensing electrode. A small domed cavity 37 may be formed in the lower surface of plug member 30 to surround sensing electrode 38. As hereinafter noted, tubular sensing electrode 38 also forms part of a ferromagnetic body for control valve 18.

[0028] Valve 18, which is used for controlling the supply of the liquid to vibrating mesh plate 52, is comprised of two components including a fixed part 39 and a changeabie or disposable part 69. The fixed part 39 is located inside plug member 30 and the disposable part 69 is affixed to the liquid reservoir. The disposable part 69 is designed in a tubular form to extend through the cavity 40 of the fixed part 39, when the reservoir is attached to plug member 30. The disposable part 69 is capable, by itself, of functioning as a shut off for the reservoir, but, in conjunction with fixed part 39, it also functions as a valve which is used to regulate the liquid flow from the reservoir to vibrating mesh plate 52.

[0029] Reservoir 17, identified more particularly as 60 in Figs. 2 et seq., is attached to the top of plug member 30 by spiral or bayonet fastening formed by openings 61 and 62. Associated projections 33 and 34 are situated symmetrically on the sides of plug member 30 and fit into openings 61 and 62 formed in the reservoir 60. Reservoir 60 may be fastened to, or unfastened from, plug member 30 by turning and pushing or turning and pulling the reservoir with respect to plug member 30. This allows the reservoir to be removed at the end of therapy for replacement, or when a different drug is to be administered to the subject.

[0030] Reservoir 60 comprises a peripheral member 63, a plate 64 made of material such as plastic, an elastic membrane 65 made of a material such as rubber, and the changeable or disposable part 69 of valve 18 affixed to the bottom of plate 64. Membrane 65 is stretched on the top of plate 64 and the two elements then pushed into peripheral member 63. Membrane 65, which is between plate 64 and peripheral member 63, is locked in the channel 66 by the plate 64. Reservoir 60 may alternatively be formed as a single part by using the modern multi component fabrication techniques using plastics.

[0031] In the middle of membrane 65, on the upper side, is a thicker area 67 of the membrane separated by ring 68. Reservoir 60 is filled with a liquid to be atomized by injecting the liquid with a syringe through area 67 inside the ring 68. Specifically, when the reservoir is empty, membrane 65 is in the pre-strained state, shown in Fig. 3a, which establishes enough pressure to empty the space beneath the membrane of liquid inside the reservoir. When the reservoir is filled with liquid by injecting it with a syringe through the membrane in the area 67, as shown in Fig. 3b, pressure inside the reservoir increases as the membrane stretches.

[0032] In operation, valve 18, which is used for supplying the liquid to vibrating mesh plate 52, is opened in response to a signal from cable 20 and liquid flows from reservoir 60 toward the mesh plate 52. The liquid flows out through the disposable part 69, which is placed inside the cavity of fixed part 39 and tubular sensing electrode 38, into contact with the upper surface of mesh plate 52. The cohesive forces in the liquid create a column of liquid extending between the lower end of sensing electrode 38 and mesh plate 52. To control the transport of liquid from reservoir 60 to mesh plate 52, the sensing electrode 38 and the mesh plate 52 function as sensing electrodes that detect the presence of liquid between the lower end of sensing electrode 38 and the rear surface 55 of mesh plate 52. The detection is based on alteration of the impedance between the two elements that function as sensing electrodes.

[0033] With the continued supply of liquid, the increased column of liquid formed between the end of sensing electrode 38 and the rear surface 55 of mesh plate 52 will significantly alter this impedance. A signal from mesh plate 52 is obtained via terminal 36 and a signal from sensing electrode 38 is obtained via conductor 100. The signals from the two sensing electrodes are inputted to an impedance sensor inside the control unit 4 via cable 20 and are used by the control unit 4 to close valve 18 to terminate or reduce the supply of liquid. When the impedance between the electrodes changes due to the liquid receding away from the end of sensing electrode 38 and the rear surface 55 of mesh plate 52 during operation of nebulizer apparatus 1, the valve opens again to allow the flow of liquid from the reservoir. The delivery of liquid to be nebulized can be controlled either by continuously vibrating mesh plate 52 and continuously regulating the liquid supply or by regulating the activation of mesh plate vibration and intermittently supplying liquid when the amount of liquid between the mesh plate 52 and the end of sensing electrode 38 is reduced.

[0034] For a nebulizer, high frequency voltage is supplied from a power source inside control unit 4 though cable 20 and terminals 35 and 36 to piezoelectric vibrating element 56 to cause the element to vibrate. The voltage causes the element 56 to contract from the normal condition, shown in Fig. 4a, to a radially decreased con-

sensing electrode 38 and stopper 75 and the tube 73 and the field strength weakens less, the shorter the distance between stopper 75 and sensing electrode 38. That means the thinner the wall of tube 73, the better the magnetic circuit. The same concerns govern the spacing between stopper 75 and plate 70. The lower magnetic field losses in the structure, the lower the amplitude of voltage that is required for controlling the valve.

[0043] Figs. 7 and 8 show another embodiment of a valve suitable for use in a liquid discharge apparatus. In this embodiment, a valve is provided internally of liquid reservoir 60. To this end, valve disk 100 is placed over opening 102 in plate 64 of reservoir 60. Means are provided to bias valve disk 100 into contact with plate 64 to close opening 102. Such means may comprise a spring in a cage mounted on plate 64 or elastic threads 104 fastened to plate 64 and arranged in a cross over valve disk 100. The pressure of the liquid when reservoir 60 is filled also serves to bias the disk into contact with plate 64 and close opening 102.

[0044] The valve of Figs. 7 and 8 also includes intermediate part 108 formed of tube 110. Actuator member 112 is loosely placed in tube 110 for movement from a lower position in which member 112 rests against shoulder 114 and a raised position. Actuator member 112 may generally be formed in the same or similar manner as stopper 75 shown in Fig. 5b. The upper end of tube 110 is closed by a plate 116 of ferromagnetic material containing hole 118. Projection 120 of actuator member 112 extends through hole 118. Tube 110 has opening 122 in the lower portion.

[0045] The fixed part 39 of the valve shown in Figs. 7 and 8 generally resembles that shown in Figs. 5a and 6 as indicated by the common reference numerals.

[0046] In the embodiment of the invention shown in Figs. 7 and 8, intermediate part 108 may be attached to reservoir 60 in the manner shown in Fig. 2. Or, intermediate part 108 may be affixed inside fixed portion 39 of the valve. Or, intermediate part 108 may be a component separate from either reservoir 60 or fixed part 39. If intermediate part 108 is fastened to reservoir 60, it can be discarded with the reservoir at the end of treatment. If it is a separate component, it can be discarded or cleaned for rouse. If it is fastened to fixed part 39, it can be cleaned after use, along with the other components of liquid discharge apparatus 1.

[0047] In use, intermediate part 108 is placed in fixed part 39, either separately, or, if intermediate part 108 is fastened to reservoir 60, when reservoir 60 is attached to plug member 30. When so assembled, the upper end of projection 120 is proximate to, but spaced from, valve disk 100 in reservoir 60, When coil 124 is energized, actuator member 112 moves from the lower position shown in Fig. 8a to the raised position shown in Fig. 8b. Projection 120 extending through holes 118 and 102 lifts valve disk 100 off plate 64, allowing liquid in reservoir 60 to flow out opening 102 through tube 110 and into apparatus 1. Shoulder 114 may be formed as a valve seat for member 108, if desired, to provide an additional means for preventing liquid flow from reservoir 60 to nebulizer apparatus 1 when member 108 is in the lower position.

[0048] Figs. 9 and 10 show a further embodiment of a valve suitable for use in a liquid discharge apparatus. In this embodiment, and similar to the embodiment of Figs. 7 and 8, a valve is provided internally of liquid reservoir 60. Valve disk 100 is placed over opening 102 in plate 64 of reservoir 60 and biased into contact with plate 64 as in one of the manners described in connection with Figs. 7 and 8. Tube 210 extends from opening 102 in plate 64.

[0049] An elastic area is provided in plate 64. The elastic area 213 is defined by ring shaped channel 211 having a smaller thickness than plate 64. The elastic area 213 can be formed in plate 64 by multi component fabrication techniques using, for example, plastics and rubber.

[0050] An actuator member 212 is placed in magnetic coil 124. Actuator member 212 may comprise a ferromagnetic sleeve which is loosely placed in a tubular recess in magnetic coil 124. The length of actuator 212 is less than the length of the recess so that actuator member may move upward when the magnetic coil is energized from a lower position in which the actuator rests against shoulder 214. Projection 220 is mounted on the upper end of actuator member 212 and extends through hole 218 in the ferromagnetic body 123 of magnetic coil 124.

[0051] When liquid reservoir 60 is attached to plug member 30 the upper end of projection 220 is proximate to, but spaced from, elastic area 213. Tube 210 extends through actuator member 212. When coil 124 is energized, actuator member 212 moves from lower position shown in Fig. 10a to the raised position shown in Fig. 10b. Projection 220 extends through hole 218 and presses on elastic area 213. Elastic area 213 moves upwardly and lifts valve disk 100 off plate 64, allowing liquid in reservoir 60 to flow out opening 102 through tube 210 into apparatus 1.

[0052] It is recognized that other equivalents, alternatives, and modifications aside from those expressly stated, are possible and within the scope of the appended claims.

Claims

1. An apparatus for discharging liquid comprising:

   a housing having an opening through which the liquid is discharged;
   a displaceable element in said housing which is subject to displacement for discharging liquid;
   means for displacing said element to cause liq-

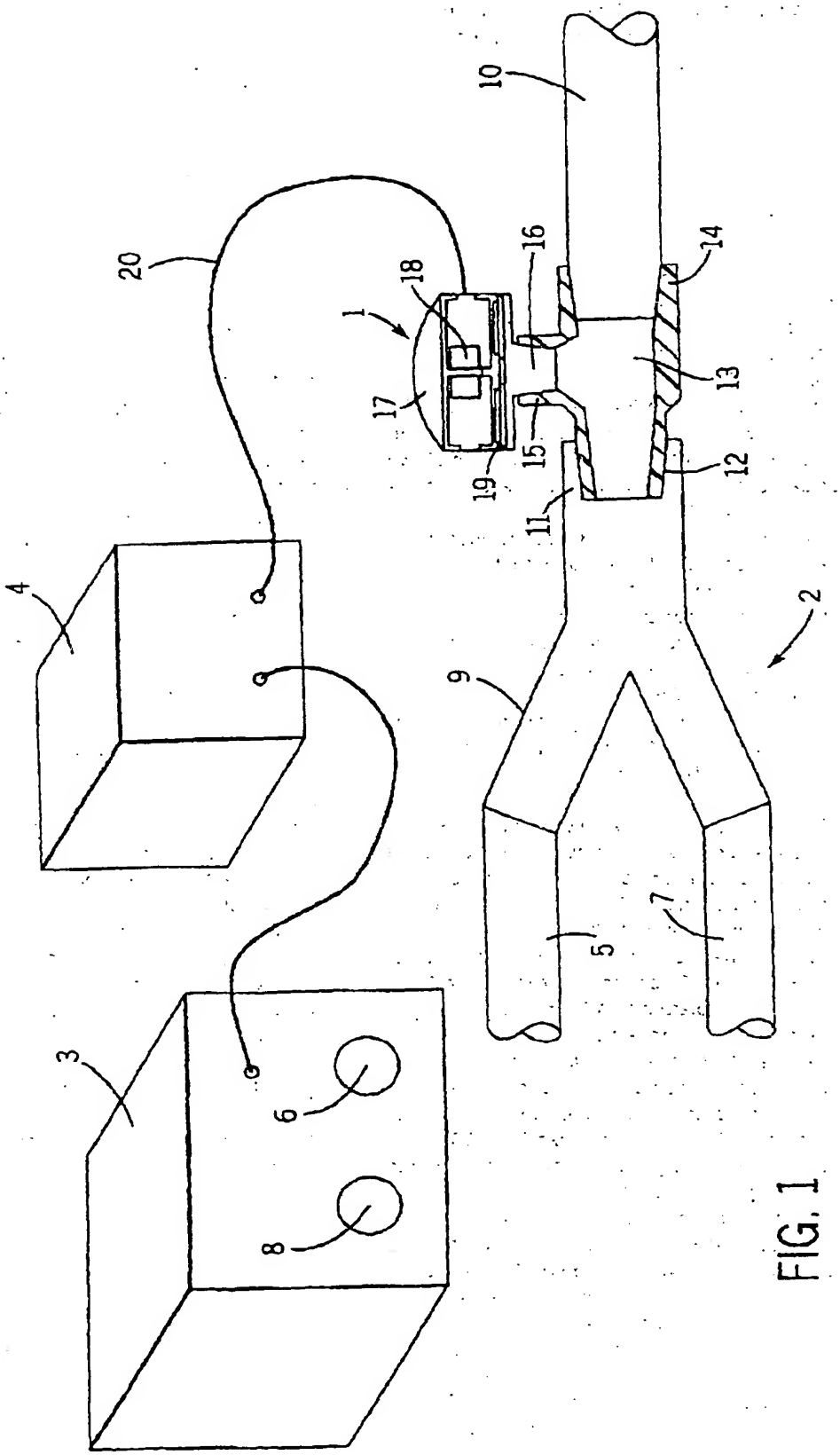

FIG. 1

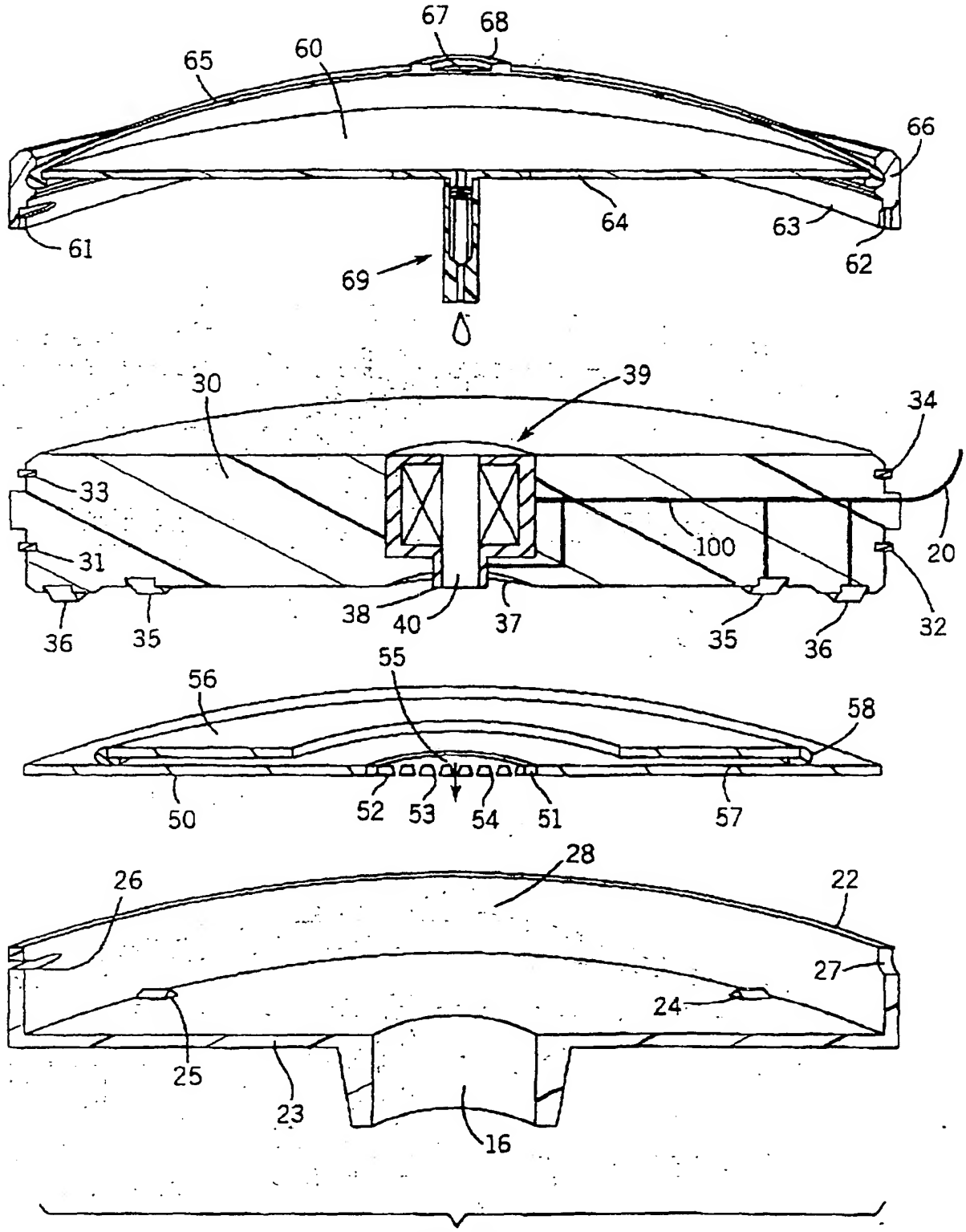
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FIG. 2

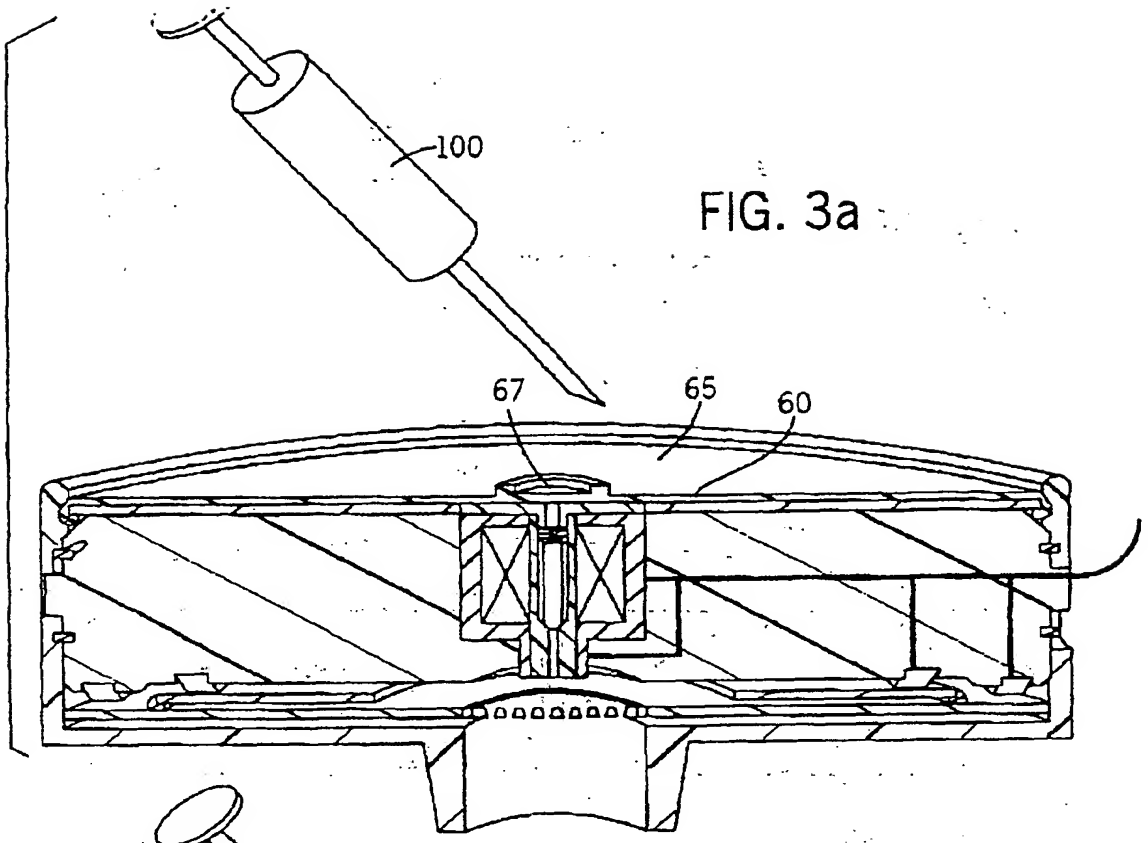


FIG. 3a

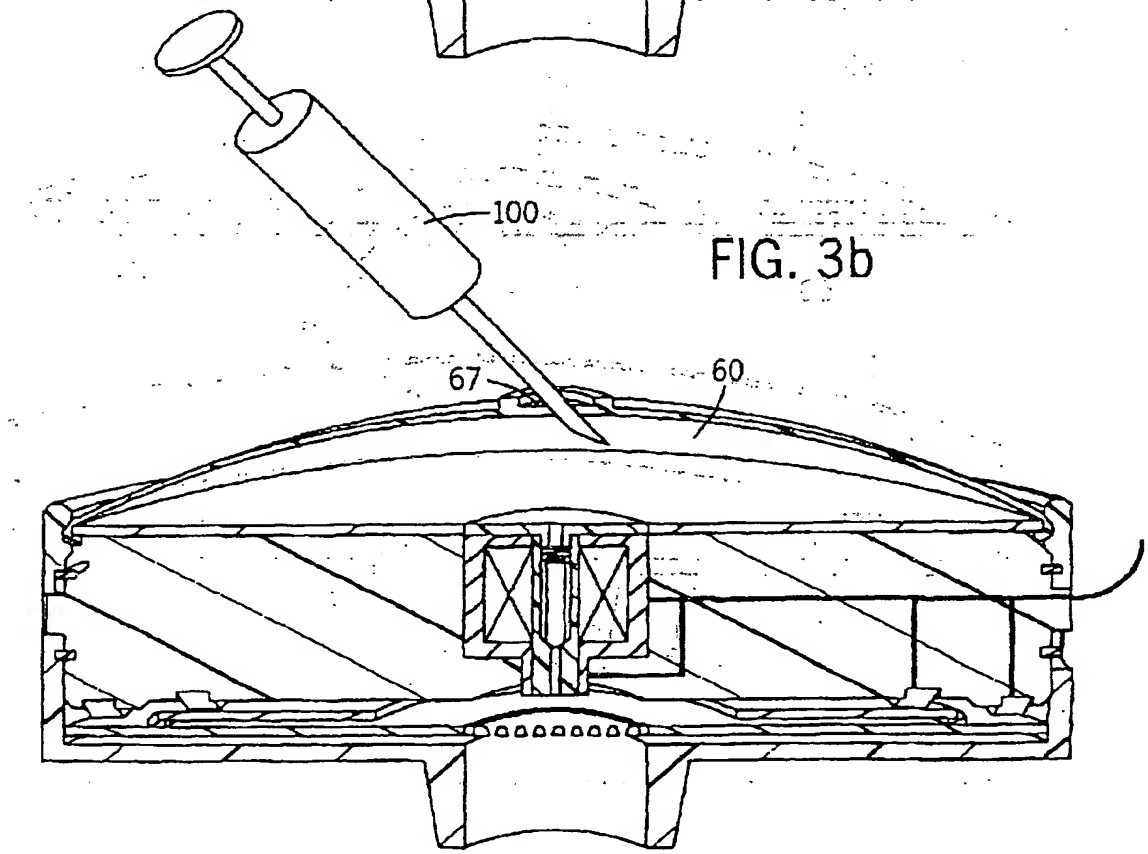
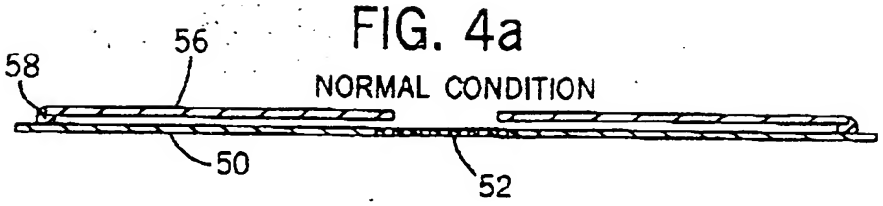


FIG. 3b

FIG. 4a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NORMAL CONDITION
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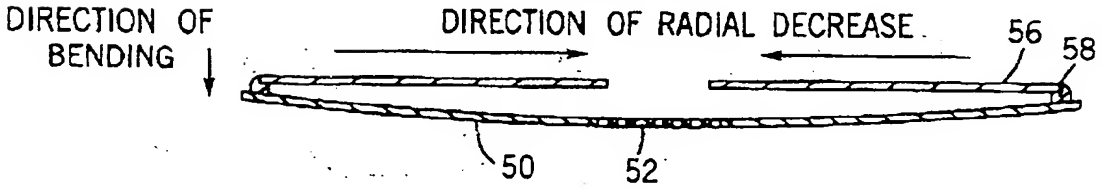
52

FIG. 4b


DIRECTION OF
BENDING
DIRECTION OF RADIAL DECREASE
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58
50
52

FIG. 5a–1

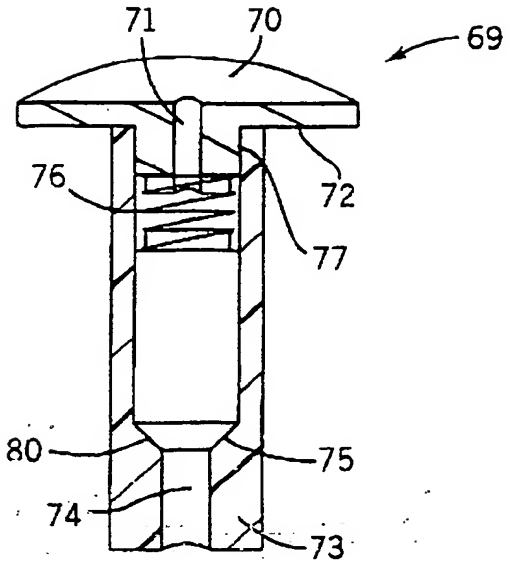
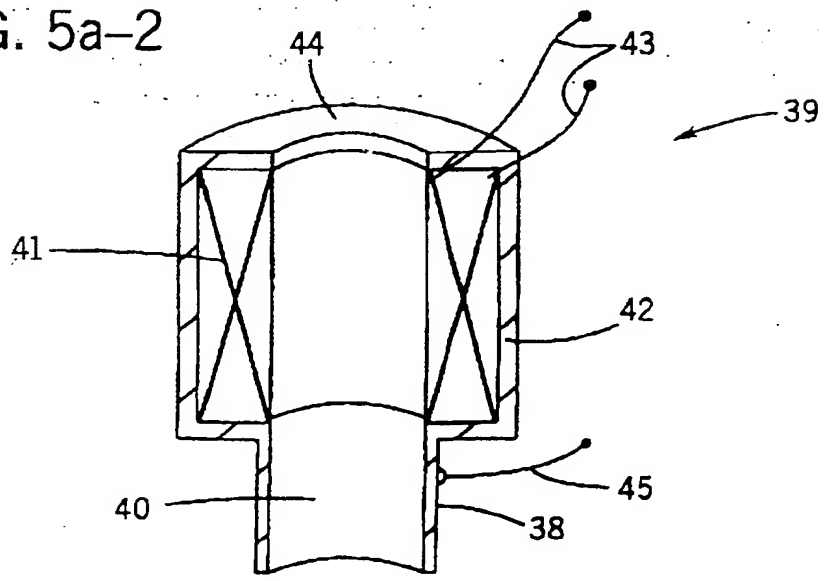


FIG. 5a–2



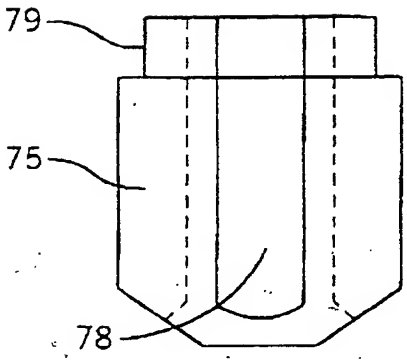


FIG. 5b–1

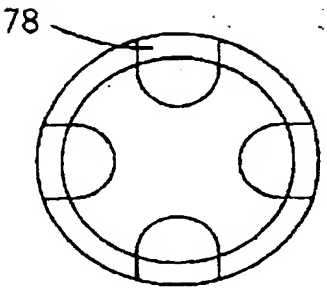


FIG. 5b–2

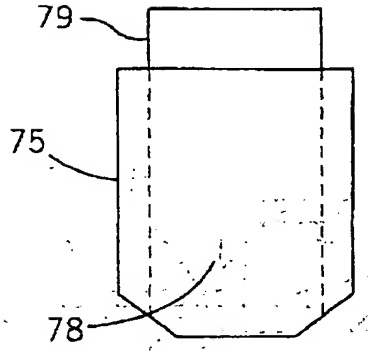


FIG. 5b–3

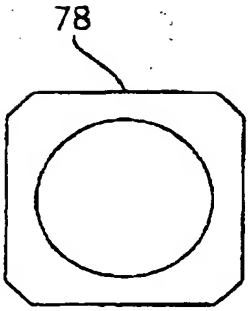


FIG. 5b–4

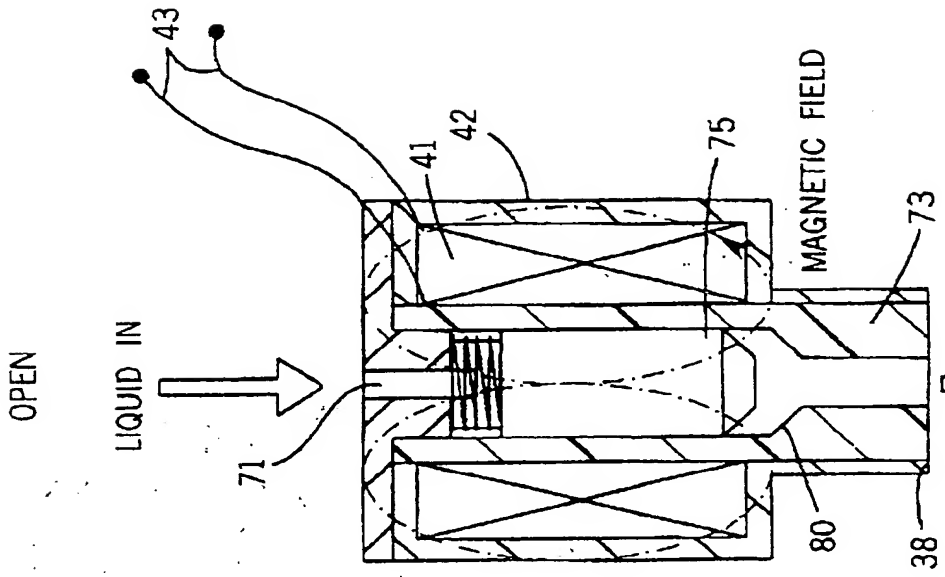
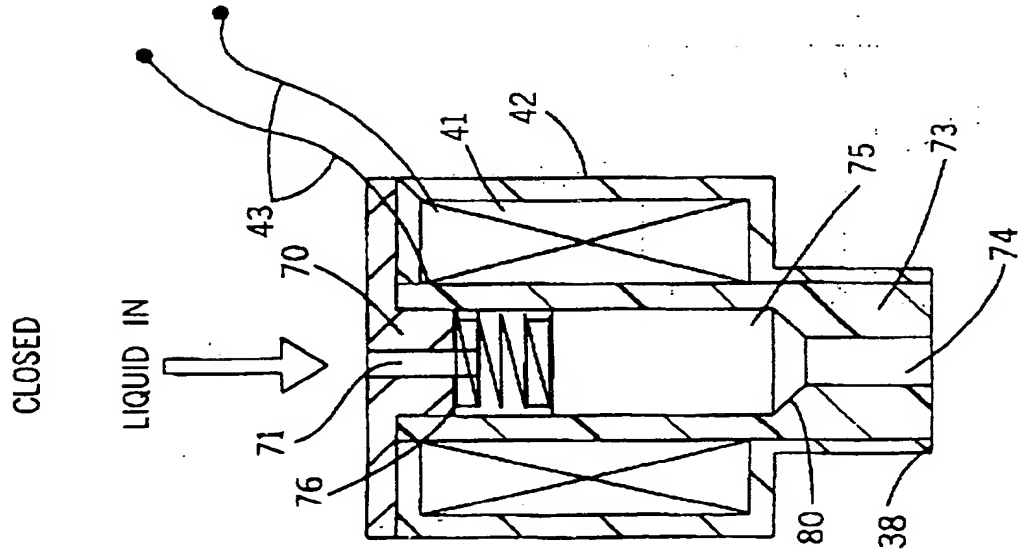

OPEN
LIQUID IN
43
41
42
75
MAGNETIC FIELD
73
71
80
38
LIQUID OUT

FIG. 6b


CLOSED
LIQUID IN
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71
76
80
38

FIG. 6a

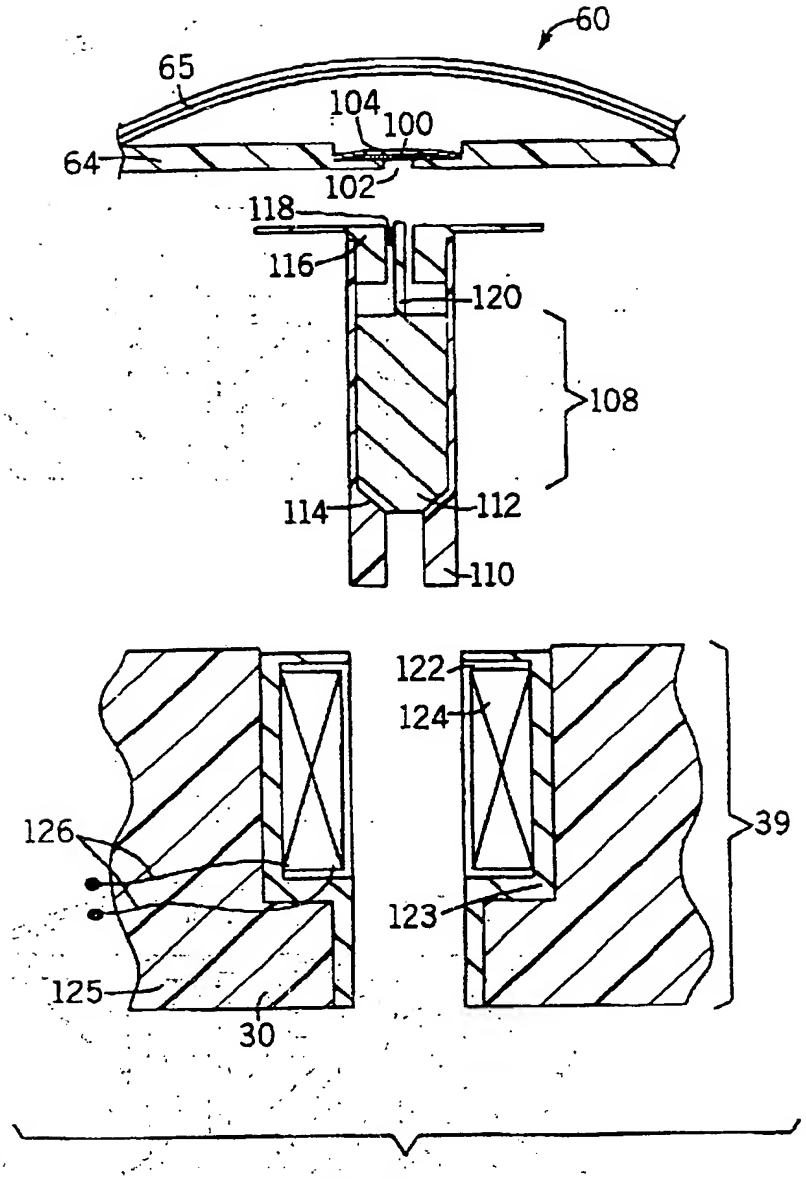
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FIG. 7

FIG. 8a

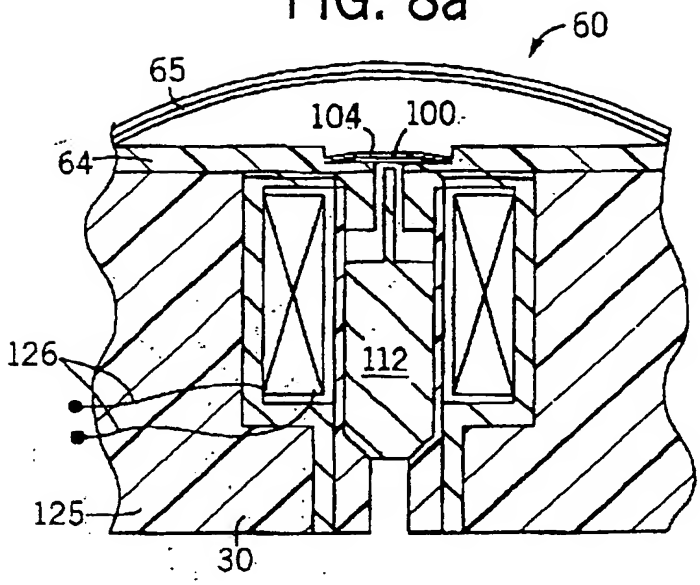
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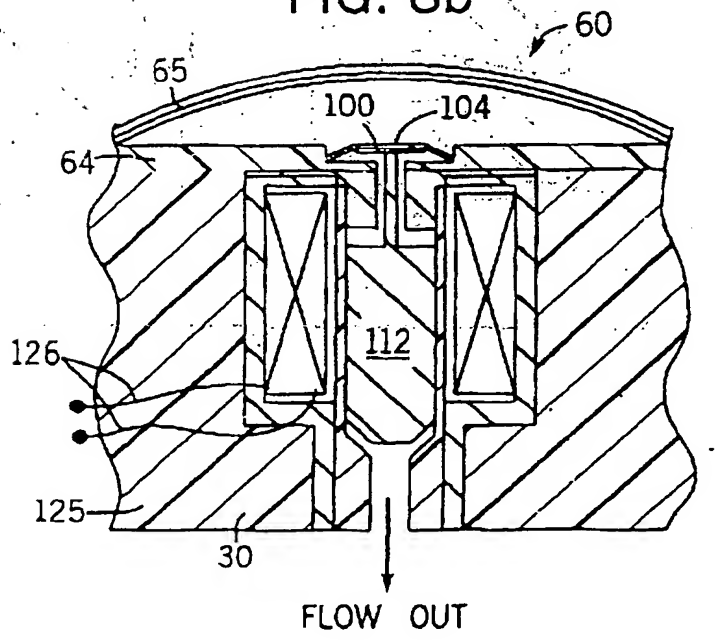
FIG. 8b


60
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FLOW OUT

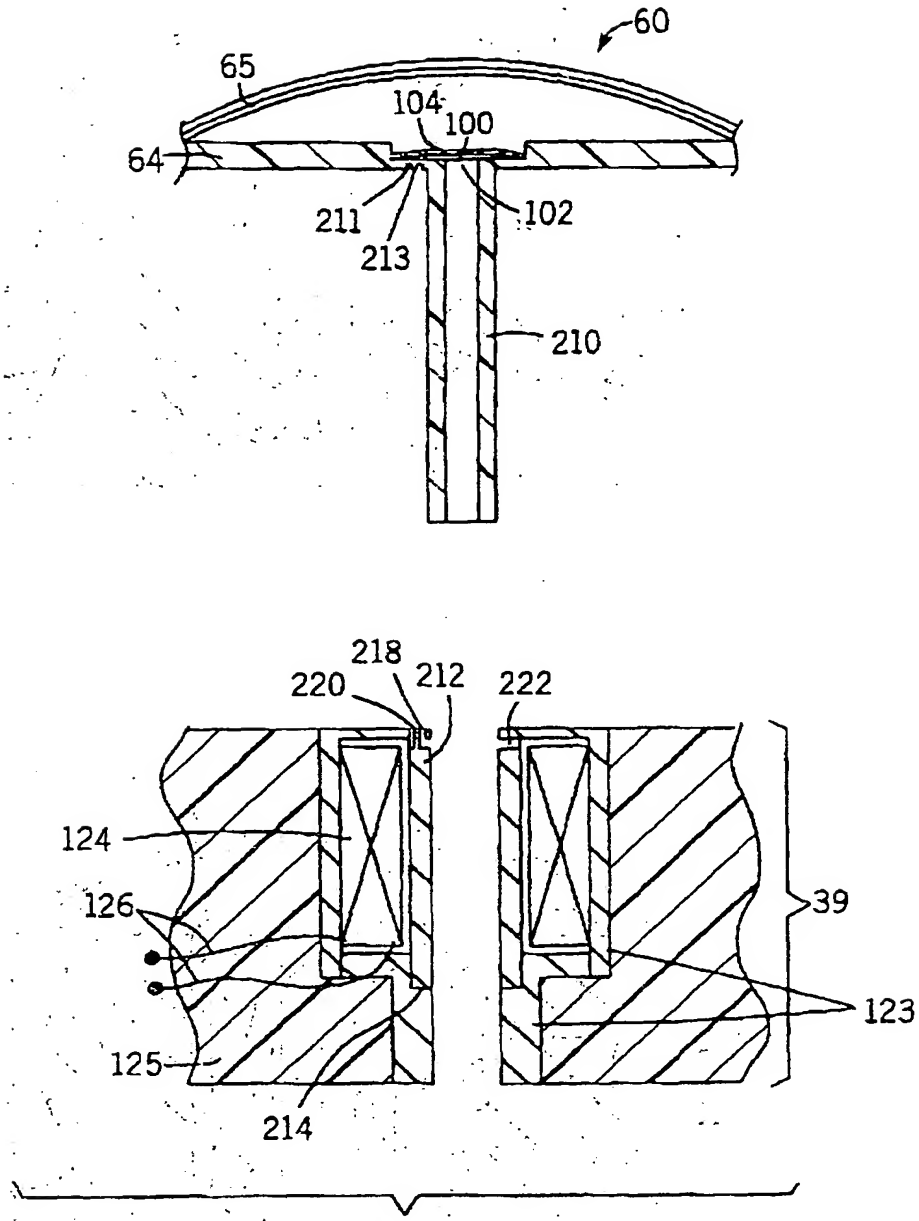
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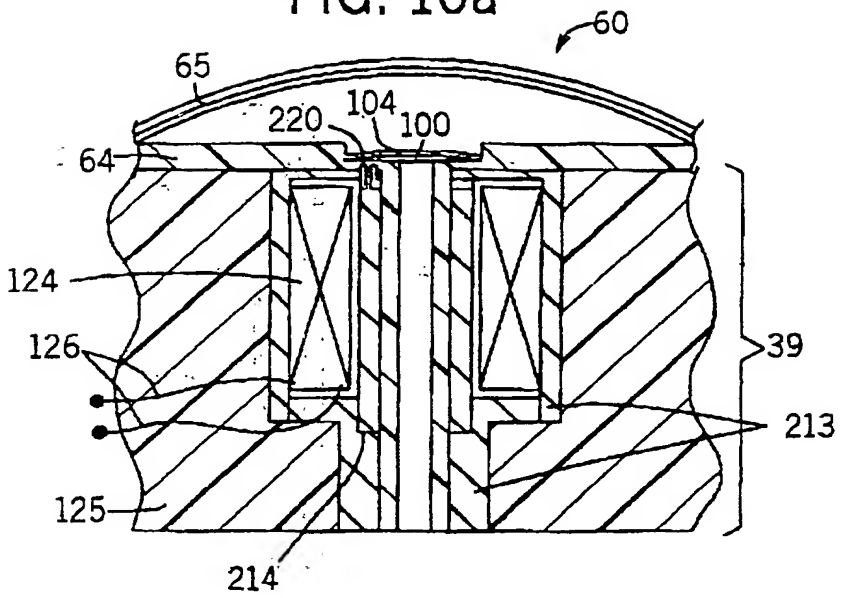
FIG. 9

FIG. 10a



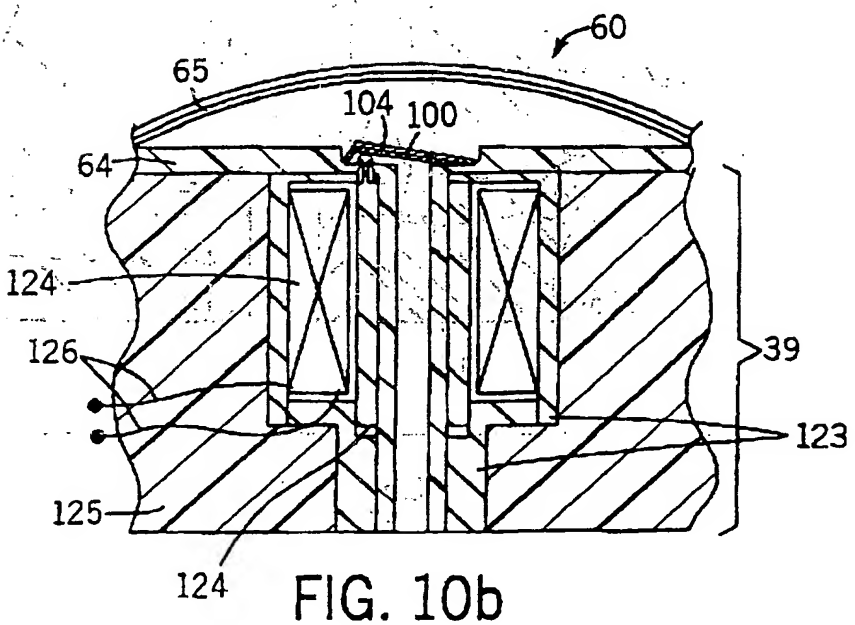


FIG. 10b

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 31 1778

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
D,A	US 5 443 059 A (KOCH JOCHIM ET AL) 22 August 1995 (1995-08-22) * abstract *	1-22	A61M11/00 A61M15/00 A61M16/20 A61M16/18
A	US 5 388 571 A (ROBERTS JOSEPHINE A ET AL) 14 February 1995 (1995-02-14) * abstract; figure 1 *	1-22	
A	US 4 210 174 A (EROSS BELA) 1 July 1980 (1980-07-01) * abstract *	1-22	
A	US 4 630 799 A (NOLAN JOHN H ET AL) 23 December 1986 (1986-12-23) * abstract *	1-22	
A	WO 99 22796 A (INSTRUMENTARIUM CORP) 14 May 1999 (1999-05-14) * abstract *	1-22	
A	EP 0 794 370 A (SIEMENS ELEMA AB) 10 September 1997 (1997-09-10) * column 1, line 3-13 * * column 4, line 6-41; figure 2 *	1-22	TECHNICAL FIELDS SEARCHED (Int.Cl.7) A61M

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	30 April 2001	Nielsen, M

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
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O : non-written disclosure
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L : document cited for other reasons

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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 00 31 1778

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30-04-2001

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